Synopsis of the PhD thesis titled

Study of Sediment dynamics along the coastal waters off Karnataka based on Remote Sensing and GIS Techniques

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Sediment dynamics along the coastal waters off Karnataka based on Remote Sensing and GIS Techniques

There is increasing interest in the study of sediment dynamics of the coastal region due to problems associated with siltation in harbours and navigation channels and due to environmental problems. In the last two decades numerical modelling has been largely used for representing the response of sediment dynamics to natural driving forces and human intervention. Numerical models require inputs of ocean measured data to drive the model and to use as boundary or initial conditions. With the conventional methods of measurements of ocean parameters, it is impossible to conduct measurements in a synoptic way. Present day satellite technology offers an alternative to the conventional oceanographic measurements in a cost effective manner and with global coverage. This research work is an attempt to couple the modern techniques of remote sensing and numerical modelling for the better understanding of ocean observation and predictability and present the results with the help of GIS.

The possibility to observe various ocean parameters and processes by existing satellite sensors, such as optical sensors, and active microwave sensors like altimeter, scatterometer are attempted. The various parameters are attempted in the present study are ocean colour by spectrometers (total suspended matter), sea-surface elevation by altimeters, and surface roughness by active and passive microwave systems, which can be used to derive information on surface wind and waves.

In the present study there were three models with different grid and mesh size were employed

1. A wave model covering the north Indian Ocean – NIO basin is considered to account the swell and wind waves. Radiation stresses(forces) were calculated for the model mentioned in 3 (chapter 4)
2. A west coast flow model driven by offshore tides velocities from a global model. Levels from this model drives the local model 3
3. A local model covering the coastal waters off Karnataka to study the sediment transport. This model takes inputs from the other models and suspended sediment concentration.

The objectives of the study are: to address the major physical oceanographic parameters like long term wave climate by hindcasting using satellite derived winds, modelling of circulation and dispersal patterns using the predicted tides with the help of global models and sea surface parameters derived by satellites, and finally to study the

sediment transport using numerical modelling and satellite derived suspended matter.

The thesis contains seven chapters and is organised in the following manner

Chapter1. **Introduction**

This chapter deals with the dynamics of west coast of India in general and sediment dynamics of the Karnataka coast in particular. The physical, biological and geological importance of the Karnataka coast has been dealt in detail. It also deals with the overall objective of study and how the thesis organised.

Chapter2. **Coastal Ocean dynamics: An overview**

The important factors influencing the dynamics of coastal waters are wind, pressure gradient force, tides and river run off. Transport of pollutants from marine outfalls of domestic and industrial waste, erosion of beaches, processes such as upwelling that control biological productivity, sedimentations, etc. are influenced by the characteristics of circulation. This chapter deals with the theoretical aspects of the ocean dynamics. Theoretical set up of coastal ocean parameters like wind driven currents, waves, and other major forces acting on the marine environment is dealt in detail. Besides these, various forces and mechanisms which influence the dynamics of ocean water are also discussed.

Winds:Wind blowing over the ocean surface causes a tangential stress ("wind stress") at the interface which acts as a vertical flux of horizontal momentum. If the upper ocean has a neutral or stable stratification, then the force imparted by the wind stress will generate a momentum flux that is maximum at the surface and decreases with depth through the water column. Consequently, a vertical shear in the velocity develops in the upper ocean mixed layer. The mechanisms by which the momentum flux extends below the interface are not well understood.

Waves: A portion of the force due to wind blowing generates waves. However, most of the wave momentum later becomes available for generating currents through wave breaking, and wave-wave and wave-current interactions.

Tides and tidal circulation: The rise and fall of the tides play an important role and can have a marked effect on material transport in the coastal and open oceans. Navigating ships through shallow water ports, intra-coastal waterways and estuaries requires precise knowledge of the time and height of the tides as well as the speed and direction of the tidal

currents. Tidal mixing of near-shore waters, where pollutants are removed and nutrients are re-circulated has special ecological emphasis. Furthermore, the study of tidal fluctuations has specific importance in understanding the circulation of the ocean and its relationship to world climatic changes. A current associated with this rise and fall is known to be tidal current. Tide and tidal currents varies from place to place. As far as the west coast of India is concerned, Bhavnagar experiences highest tidal range of about 12m, whereas in Karnataka it is of the order of 2m.

In short wind, tides and wave breaking along with many other mechanisms determines the sediment transport of the coastal waters. The chapter also explains the equations governing the movement of fluid parcel. Once the water starts moving, it is governed by the basic laws of fluid dynamics. Fluid mechanics used in oceanography is based on Newtonian mechanics modified by our evolving understanding of turbulence.

Chapter 3 Materials and methods

In this chapter, the principles of remote sensing, role of remote sensing in oceanographic studies, different types of data used for the present study and corrections applied for data extraction, features of study area and the methodology adopted for extracting the information are discussed. This chapter contains mainly two sections. First section deals with principles involved in the extraction of information from remotely sensed data and the second section deals with the data and methodology adopted in the present study.

The possibility to observe various oceanic parameters and processes by existing satellite sensors, such as optical instruments, infrared radiometers, passive microwave radiometers, and active microwave systems like altimeter, scatterometer, SAR are discussed. The basic parameters are: sea-surface temperature observed by infrared radiometers, ocean colour by spectrometers, sea-surface elevation by altimeters, and surface roughness by active and passive microwave systems, which can be used to derive surface wind and waves. Brief discussions on data types, sources, and related instruments explaining their technical characteristics, measured parameters, their accuracies, and associated retrieval algorithms and corrections applied to each product are presented in data and methods section. This section includes the data used for the present study and the methods involved in the extraction of various geophysical parameters.

Chapter 4- North Indian Ocean wave hind casting using SWAN

This chapter is devoted to the analysis of waves and wave hindcasting using remotely sensed wind fields. A SWAN wave model has been setup aiming to establish a long term time series (minimum one year) wave field for sediment transport modelling. To account the swell waves, the model area is extended to the North Indian Ocean basin. Even though we were aiming to establish a model for the Karnataka coast, the validity of the model was compared for few more points like Pipavav and Chhara (measurements were available for these points) and extended the time period from 2000 January to 2004 December to assure the local model validity. A non stationary SWAN model was set up for the area covering 0°-26.5°N latitudes and 50°-100°E longitudes (North Indian Ocean) with a regular grid 0.5° spacing in spherical coordinate system. Daily averaged scatterometer winds from QUIKSCAT referred to 10m covering 2000-2004 periods were used for wave hind-casting. Results were compared against the UKMO model results of off-Pipavav as well as the data from buoys located near Mangalore port (2000-2002) and one from the buoy located near Pipavav port (2000-2003). In addition to the wave parameters, radiation stresses (forces), an input for sediment transport modelling, is also computed.

The focus of the study is on coastal and marine environment off Karnataka coast. The wave model requires the wave spectra as well as wind fields in order to generate the information on wave conditions. In order to account the swell waves, entire North Indian Ocean is considered and assumed that waves south of the equator is negligible. Since the results from this model appear to be reasonable, the existence of swell at the southern boundary of the model is not examined in detail. But the wave field generated by SWAN model during the present study has close resemblance with that of Wave Watch-III model

Potential use of satellite derived wind field for coastal and oceanic wave field was successfully utilised for long term wave hindcasting. The SWAN model predicted the variations of Hs and Tm for North Indian Ocean basin. The results from this model have to be utilised for sediment transport modelling. This in combination can used to assess the various levels of wave energy on the coast that can result from variations in deep water wave climate.

Computed wave forces for the local Karnataka model covering the period from January to December 2001 was extracted and will be fed to sediment transport model to account the wave related sediment transport near the shore.

Chapter 5- Hydrodynamic modelling- West coast of India

A hydrodynamic model for the west coast of India was with a radiative boundary condition was utilised for establishing the currents along the west coast of India for the period January to December 2001. To establish the validity of the local nested model for sediment transport modelling, it was necessary to extend the model boundary to points were the validation data was available. The present model was driven with level and velocity components from the global tidal model TPXO. Model is validated against the predicted tides from ATT of standard ports as well as secondary ports and available tidal streams at the diamond points. Here, an attempt has been made to establish the working model with tidal boundary condition. The validity model was compared with the ATT predicted tides and Tidal steams of admiralty chart no 1486. The TELEMAC model is utilised for predicting the hydrodynamics of the west coast of India. This model runs with flexible mesh with finite element method. The model can simulate depth integrated tidal flows in estuaries and seas including the presence of drying banks. It can also simulate flows in rivers including turbulence structures resulting from flow obstructions and transcritical flows. The advantage of using finite elements lies primarily in the possibility of using a very flexible grid. This is superior to using an orthogonal curvilinear grid as the user has far more complete control over grid refinement with a finite element system. Recently the historic TELEMAC modelling systems has released for research purpose. The TELEMAC model has wider applications which includes; studies of tidal flows, storm surges, floods in rivers, dam break simulations, cooling water dispersion and infill of navigation channels.

Hydrodynamic model validation

Level: Model free surface data was compared against the ATT predicted tides at Karachi, Sikka, Okha Pipavav, Dahej, Rewas, Trombay, Ravadanda, Ratnagiri, Murud Karwar, Kumta, Batkal, Kundapur, Mangalore and Cochin.

Tidal streams: Tidal streams of British Hydrographic Office (BHO) Chart no 1486 were also compared against the model velocities of spring and neap tides. Even though the velocity values mentioned at the admiralty diamonds on spring and neap tides are based on the very

short term observation as well as estimates on the data collected at different period, it can be used as an estimate of the tidal currents in the absence of other data.

From the hydrodynamic model velocities and levels are extracted for the local model which finally acts as the boundary forcing for the sediment transport model.

Chapter 6 Sediment transport modelling

Sediment transport modelling methods are aimed at providing information regarding the movement of sediment within hydrodynamic systems. Outputs from a sediment transport model include estimates of suspended sediment concentrations, rates of sediment erosion and deposition and sediment transport pathways. Sediment transport models are based on outputs from hydrodynamic models. In the present study levels and currents from the hydrodynamic model is coupled with wave forces under the influence of wind is numerically solved for describing the sediment movements for the period covering January to December 2001 .

Fundamentally the sediment transport model uses inputs from SWAN model (wave forces/radiation stresses), flow pattern from hydrodynamic model under the influence of wind fields from QuikSCAT and validation procedure will be based on the OCM derived total suspended matter (TSM). A weekly averaged sediment transport maps are generated interpreted and is presented in GIS platform.

The results are reformatted to read by open source software and made available to interpret, extract, generate spatially and temporally varying maps of wind, waves currents and sediment.

Chapter7 is devoted to summary and scope for the future work. This chapter also deals with the use of GIS and other open source software to present the results with spatial and temporal variability.